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A preliminary study on the relationship between the complexity of the sagittal suture and cranial dimensions

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The paper presents the results obtained from analysis of the correlation between cranial dimensions (length, width, and height) and indices against the complexity of the sagittal suture, which was expressed as the ratio between absolute sutural length to the linear length of the suture. The statistical study on 29 skulls shows a significant negative correlation between the height/width index of all skulls and suture complexity (r = –0.78 for male, r = –0.70 for female skulls) and a negative correlation between cranial height and suture complexity in male skulls only (r = –0.49). This implies that lower and broader skulls have a more complicated sagittal suture. Correlations of the height/length and width/length ratios were assessed as statistically insignificant in both sexes.

Key words: cranial indexes, sagittal suture, suture complexity

INTRODUCTION

The bones of the upper skull meet along five sutures, which provide growing room for the rapidly expanding brain. The sagittal suture joins two parietal bones in the mid-sagittal plane and its protrusions extend horizontally from edge to edge of two opposing bones. The interdigitations, which are present along the opposing edges of the parietal bones, interlock precisely in the suture. The sagittal suture can be serrate or dentate, thus facilitating great resistance. This suture plays an important role in normal cranial development and growth [9, 10]. The sagittal suture enables transverse growth of the skull and the vault may considerably increase its width from childhood to adolescence. Otherwise, if cranial growth is interrupted by premature ossification, a scaphocephalic skull results as a consequence of sagittal synostosis. This disorder involves an abnormal development of the skull and results in an unusually long and narrow head shape [11]. In spite of numerous studies upon human crania, there has been no extensive examination of the associations between cranial dimensions and sutural complexity. It was because of the lack of data in the literature concerning this relationship that this study was undertaken. The aim of this study was, then, to evaluate whether the complexity of the sagittal suture correlates with cranial dimensions (length, width, height) and cranial indexes.

MATERIAL AND METHODS

Analyses were performed on the non-obliterated sagittal sutures of adult individuals. The skulls investigated are housed in the collections of the Anatomical Museum of the Anatomical Department of the Jagiellonian University.

The relationship between the complexity of the sagittal suture and cranial dimensions was studied on a series of 29 human skulls (19 males and 10 females). Analysis was performed on adult, non-deformed dry skulls, with a clearly visible pattern of sagittal suture on the external surface of the skull.

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The skulls studied were all without a metopic suture, which can be regarded as a continuation of the sagittal suture. The presence of a metopic suture may alter the rules of cranial growth and therefore skulls with a metopic suture were rejected.

An outline of the cranial suture was traced with a marker that could draw a thin line along the suture analysed on transparent tape, which had been placed on the external surface of the skull. These traced silhouettes of cranial sutures were scanned with a flat bat scanner and the digitised images then processed to obtain a line of 1 pixel in width. Such outlines of cranial sutures were processed by software which enabled the length of the suture to be measured.

Cranial measurements were taken on the external surface of the skull with a sliding calliper and a spreading calliper according to anthropological standards [6, 7].

Cranial dimensions were expressed by absolute diameters: maximum cranial length (g-op), maximum cranial width (eu-eu) and cranial height (ba-b). The interrelationships between cranial diameters (length, width and height) were expressed by three cranial indices: (eu-eu/g-op)•100, (ba-b/g-op)•100, (ba-b/eu-eu)•100, which indicate the proportions between cranial diameters and classify skulls as long, short, narrow, high, etc.

Two measurements of the sagittal suture were performed to evaluate the coefficient of the sutural complexity (the linear length of the sagittal suture — the direct distance from bregma to lambda and the total length of the sagittal suture — the length of the curved line that follows the outline of the suture). Sutural complexity was expressed as the ratio between absolute sutural length to the linear length of the suture.

The relationship between the pairs of variables examined has been expressed in terms of the correlation coefficient. The significance level calculated for each correlation equalled 0.05. Since this parameter is valid as a measure of relationship only if the two-dimensional distribution under examination is normal, the variables analysed were statistically tested using the Shapiro-Wilks W test of normality. If the W statistic is significant, then the hypothesis that the respective distribution is normal should be rejected.

RESULTS

In the case of the cranial variables studied the statistic W of the Shapiro-Wilks test is not significant, so the normal distribution was accepted for the data analysed.

Mean values and the range of variation of the craniometric data of the calvaria and the sagittal sutures are presented in the Tables 1 and 2. The correlation matrix of the metric traits under examination is displayed in Tables 3 and 4.

A statistically significant negative correlation between cranial height and suture complexity was detected only in male skulls, while cranial length and width do not correlate significantly with suture complexity in either sex.

Pearson's correlation coefficient also supported a strong negative correlation between suture complexity index (CI) and height/width index (ba-b/eu-eu). This correlation is statistically significant in both male and female skulls. There is no significant correlation of the height/length and width/length index. It may, therefore, be concluded that complexity of the sagittal suture is related to the proportion between cranial height and width. This implies that skulls with a low width/height index have a more complicated sagittal suture (Fig. 1). According to the classification of the width-height index these skulls will be termed *tapeinocranus* (range of index: x-91.9). For the skulls with a higher width/height index, the complexity index of the sagittal suture is lower and its values depict instead their weakly complicated sutures with a pattern of wavy lines.

DISCUSSION

A number of studies have examined quantitatively cranial morphology and patterns of sutures but there is no detailed evidence for the relationship between sutural morphology and cranial dimensions or shape [2, 3, 5]. Measurements of suture complexity seem to be important for the study of cranial growth and it may be fruitful to evaluate temporal and geographical variations in sutural morphology and its relation to the cranial dimension and form. This knowledge might be helpful in racial taxonomy or sex determination, if significant relationships between suture complexity and cranial dimensions could be established in distinct morphotypes.

A cranial index expresses the interrelationship between two defined dimensions of the skull and therefore can be regarded as an indicator of cranial shape. Skull length, width and height measurements were used to assess the influence of increased cranial dimension on sutural complexity. The increase in skull dimensions is ultimately related to the growth of the brain [8]. The entire construction of the brain-

Table 1. Statistical data of the skulls analysed

Variable	Sample		Mean		Minimum		Maximum		Sd	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
g-op	19	10	174.95	165.10	160.0	155.0	185.0	178.0	7.43	7.43
eu-eu	19	10	142.79	139.30	129.0	131.0	155.0	147.0	7.15	4.30
ba-b	19	10	131.00	127.40	120.0	118.0	145.0	135.0	6.16	5.62
eu-eu/g-op	19	10	81.68	84.45	75.57	79.21	90.12	88.46	4.00	2.68
ba-b/g-op	19	10	74.99	77.25	68.65	70.24	84.30	83.87	4.39	3.77
ba-b/eu-eu	19	10	91.90	91.53	81.94	84.29	100.0	99.24	5.19	4.83

Table 2. Mean and range of variation of the complexity of the sagittal suture

Variable	Sample		Mean		Minimum		Maximum		Sd	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
CI	19	10	3.33	3.71	2.19	2.63	4.89	4.92	0.79	0.66

Table 3. Correlation matrix of calvaria diameters and sagittal suture complexity

Diameter	CI	
	Male	Female
g-op	0.08	0.05
eu-eu	0.44	0.38
ba-b	–0.49*	–0.56

*Denotes statistically significant correlation, $p < 0.05$

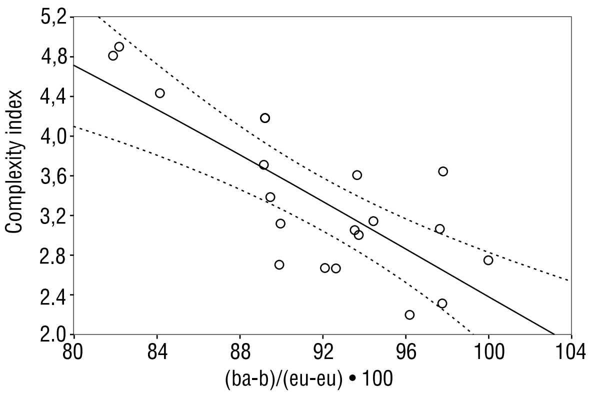

Figure 1. Correlation between the complexity index of the sagittal suture and the height/width cranial index for male skulls.

case facilitates this process mainly thanks to the sutures, which are the sites of bone growth and enable a small amount of movement. On the other hand the sutures must be strong enough to keep the bones together and protect them from dislocation [4].

Table 4. Correlation matrix of the cranial indices and sagittal suture complexity

Cranial index	CI	
	Male	Female
(eu-eu/g-op)•100	0.38	0.27
(ba-b/g-op)•100	–0.45	–0.56
(ba-b/eu-eu)•100	–0.78*	–0.70*

*Denotes statistically significant correlation, $p < 0.05$

The cranium and its sutures should be treated as one functional system, the components of which cooperate during cranial morphogenesis. Otherwise, any disturbances of this system may cause severe cranial and facial malformations [1]. During individual development the dimensions of the calvaria directly reflect the form of the growing neural mass, while the sutures have to counter separation of the calvarial bones and permit motion between them. When the parietal bones are passively carried apart with the expanding cerebral capsule, their areas are increased by deposition of bone in the sutural margins. They undergo significant morphological changes, which often produce an irregular shape of bony edges involved in suture formation.

In our study we hypothesised that variation in the complexity of the sagittal suture is influenced by interaction between the length, width and height of the skull, which in turn are governed by expansion of the brain. This hypothesis was examined using a group of adult skulls treated as a final result of the growth process.

We only observed a negative correlation between cranial height (ba-b) and suture complexity in male skulls but a negative correlation between suture complexity and the width/height index was observed in both sexes. These correlations probably reflect morphological relationships between the brain, cranium and the sagittal suture during the growth of the head. These can be explained in the following manner.

With increased transverse diameter and limited vertical growth, the parietal bones of the skulls were subjected to separation from each other by intrinsic forces derived from the expanding brain. In this case, the sagittal suture be strong enough to prevent the parietal bones from lateral dislocation. This could be achieved by increased sutural complexity brought about by rapid osteogenesis in the sutural area and producing a compensatory amount of bone.

High skulls, in which the proportions between width and height are more or less equal, have a less complicated sagittal suture than skulls with a low width/height index, as during cranial growth compensatory production of bone occurs not in the sagittal suture but in the sutures located in the lateral wall of the skull. In this case the parietal bones are not subjected to extensive forces of separation but are instead elevated vertically by the growing brain. Here the low complexity of the sagittal suture may result from gradual osteogenesis in the sutural area and lack of extensive counteraction to the transverse dislocation of the parietal bones.

From this study we conclude that the complexity of the sagittal suture is related to cranial dimensions (width and height) and their proportions, whereas cranial length does not influence its complexity. Thus we also presume that brain expansion in a vertical or transverse direction is, in contrast to midsagittal expansion, crucial for determining the complexity of the sagittal suture.

We tested our hypothesis on a cranial set which did not present a vast range of variability in cranial diameter. A consistent result should be obtained in order confirm the view that there is a mutual and direct relation between cranial dimension and sutural complexity.

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